A variety of approaches to the frontal cranial base for aneurysms of the ACoA have been described over the last years. Lately, smaller approaches have been favored due to better cosmetic results and fewer approach-related complications. In general, many of these minimally invasive approaches are variations of orbitozygomatic, pterional, or supraorbital approaches. In 2001, we proposed a minimally invasive transorbital keyhole approach especially for ACoA aneurysms. The approach was regarded as a step toward the ideal of purely extraaxial and safe control of ACoA aneurysms without the necessity to resect parts of the gyrus rectus or to use unnecessary brain retraction.

After its introduction this skull base approach was regarded as having a higher morbidity as well as problematic cosmetic results due to the partial removal of the orbital roof and the lateral orbital rim. The goal of the present study was to investigate the early as well as the long-term approach-related morbidity of the transorbital keyhole approach. Additionally we studied long-term cosmetic results in our patient series.

Methods

We analyzed the approach-related morbidity and cosmetic results in 71 patients who underwent surgery via the transorbital keyhole approach between January 2004 and December 2008 for cerebral vascular pathologies. The orbitocraniotomy requires 2 bur holes, 1 placed in the position of the pterional keyhole bur hole, the other lateral to the supraorbital nerve above the upper orbital rim as the medial aspect of the craniotomy. Both bur holes are connected through the frontal bone using a small diamond drill.

Object. In 2003 the authors introduced a minimally invasive transorbital keyhole approach. Because this approach requires removal of the orbital rim and orbital roof, there have been concerns regarding perioperative morbidity, long-term morbidity, and cosmetic results. The authors evaluated approach-related morbidity and cosmetic results in their patients to determine the rate of complications and compared this to published reports of similar approaches.

Material. Seventy-one patients (41 female, 30 male) underwent operations using this approach between 2004 and 2008. Immediate approach-related morbidity was recorded after the operation. Late morbidity was determined after 7 months by an independent examiner while cosmetic results were self-rated by the patient using a questionnaire.

Results. Fifty-one (72%) of 71 patients had no postoperative complications and 12 (16.9%) had minor complications, the most common of which was subgaleal CSF collection (7.0%). Other minor complications included facial nerve palsy (2.8%), hypophagia (2.8%), peri orbital swelling due to periorbital hematoma (2.8%), and subdural hematoma (1.4%). Major complications requiring surgical revision occurred in 4 patients (5.6%); these were CSF fistulas in 2 patients, pneumocephalus in 1 patient, and a hematoma in 1 patient. Forty-nine (90.7%) of all 54 examined patients rated the cosmetic results as very good or good. Major long-term morbidity was hyposmia or anosmia (14 patients) followed by hypoesthesia around the scar (9 patients).

Conclusions. The transorbital keyhole approach is a feasible approach with a low-risk profile for postoperative or long-term morbidity and excellent cosmetic outcome. (DOI: 10.3171/2010.9.JNS1095)
were analyzed retrospectively from our database. Prospective, the patients were examined in our outpatient clinic. Early morbidity was considered any approach-related complication immediately after the operation until discharge. Approach-related was any complication that involved the wound, the craniotomy, closure of the dura, or content of the orbit and function of the eye.

We differentiated between minor and major complications. Minor complications exceeded the level of expected postoperative development but posed no threat to the patient and never necessitated surgical treatment or prolonged the duration of stay. Severe complications were defined as any event making a surgical revision necessary or any other sort of specific treatment and generally prolonged the duration of hospital stay. Long-term morbidity was defined as any approach-related complication recorded during patient follow-up.

Cosmetic results were recorded by investigation through an independent examiner (S.L.) and a self-rated questionnaire. The follow-up examination assessed whether atrophy of the temporal muscle was present, if the orbital rim was symmetric, and what the scar looked like (length, color, and surface of scar). Additionally, dysesthesia and/or pain around the scar, function of facial and olfactory nerve, and function of the eye were investigated. When examining the eye we checked bulbar movement and vision, eyelid closure, and if proptosis or enophthalmos were present. The patient rated their satisfaction with the postoperative cosmetic result in 1 of 4 categories: very good, good, moderate, or poor. We also asked the patients to further explain their rating, especially when the patient was dissatisfied with the result.

**Results**

Seventy-one patients were included (41 female, 30 male), with a mean age of 53.6 years (range 12–81 years). Operation via the transorbital keyhole approach was performed due to acute SAH from ruptured ACoA aneurysms in 58 patients, and 9 patients underwent surgery due to unruptured ACoA aneurysms. In addition, 2 arteriovenous malformations, 1 epidermoid, and 1 craniopharyngioma located around the ACoA complex were exposed via the transorbital approach. A left-sided approach was used in 41 cases and a right-sided approach in 30 cases.

**Early Results and Postoperative Complications**

In 51 patients (72%) no complications or approach-related morbidity was observed. In our patient group no case of supraorbital numbness due to traction or injury of the supraorbital nerve was evident.

**Minor Complications.** Two patients showed hypophagmas due to orbital venous congestion, in one of these accompanied by ptosis. Hypophagmas describes a hemotoma of the conjunctiva without involvement of the cornea and without visual impairment. The hemotoma resolves within 1–2 weeks without specific treatment. Causes for hypophagmas are direct trauma of the bulbus, vessel rupture due to elevated blood pressure, or venous congestion. Two patients experienced incomplete facial nerve palsy of the forehead branch with reduced eyebrow movement.

Five patients (7.0%) showed subgaleal collection of CSF but without a CSF fistula. With application of lumbar CSF drainage the CSF collection vanished. The application of lumbar drainage did not lead to any subsequent complications or prolonged hospital stay and was therefore not regarded as a major complication.

One patient (1.4%) showed a small subdural hematoma without space-occupying effect on a postoperative CT scan. This hematoma was not visible on a later CT scan obtained after 3 days. Two patients (2.8%) had a periorbital hematoma without effect on eyelid closure or bulbar movement but with a pronounced periorbital swelling that exceeded the expected extent of postoperative swelling. Periorbital swelling in general was not considered a complication when it subsided within 3–5 days.

**Major Complications.** Four patients (5.6%) needed operative revision—in 2 patients due to CSF leak, in 1 patient due to pneumatocephalus, and in 1 patient because of a compressing intraorbital hemotoma causing hypophagmas through venous congestion. In the patients with CSF leak or pneumatocephalus an opening of pneumatized cells of the frontal sinus was identified and was closed using a muscle patch in combination with galeal or peristeal patch and fibrin glue. In 27 patients (38%) the frontal sinus had to be sealed due to intraoperative penetration. The intraorbital hemotoma was evacuated by removing the bone flap. A source of bleeding could not be identified and the bone flap was reinserted.

**Other Complications.** Four patients underwent reoperations due to necessary recirling of an ACoA aneurysm. The correct positioning of the aneurysm clip was possible without widening the craniotomy or using retraction by using the preexisting approach. These revisions were unrelated to the initial approach and the patients suffered no complications from the first operation.

Four patients died between 6 and 34 days after the operation. All suffered from severe aneurysmal SAH. All deaths were unrelated to the operative approach. Table 1 summarizes the early postoperative morbidities.

**Late Morbidity and Cosmetic Results**

After an average of 7.3 months patients were examined in our outpatient clinic. A neurological examination was conducted and the cosmetic results as experienced by the patients were recorded in an interview using a predefined questionnaire. As stated above, 4 patients had died and 10 patients (14.1%) were either lost to follow-up or refused to participate in the study.

**Late Morbidity.** Neurological examination results were available in 57 patients (80.3%). Thirty-four (59.6%) of these 57 patients experienced no neurological sequelae related to the transorbital approach. Fourteen patients (24.6%) complained about persisting anosmia (10 with anosmia, 4 with hyposmia), 1 in combination with dysesthesia surrounding the scar, 8 patients (15.7%) with dysesthesia solely around the scar, and 2 patients (3.5%) continued to have partial facial nerve palsy of the temporal branch (rami frontalis and orbicularis). The other patient with facial nerve palsy fully recovered early after the operation.
There was no deficit in vision or bulbar movement in the examined patients apart from 1 patient who continued to suffer from an abducent nerve palsy and central facial nerve palsy as sequelae of severe SAH unrelated to the surgical approach.

**Cosmetic Results.** We obtained 54 evaluations (80.5%) of cosmetic result. Thirty-five patients (64.8%) rated the cosmetic results as very good, and 14 (25.9%) as good. Four patients (7.4%) considered the result moderate while 1 (1.8%) was very unsatisfied with the result and rated it as poor. Exemplary pictures of patients of all cosmetic categories are demonstrated in Fig. 2.

The major cosmetic complaint concerned atrophy of the temporal muscle. In 12 (22.2%) of 54 patients muscle atrophy was more or less evident, although only in 5 (9.4%) of 53 patients was muscle atrophy clearly visible. However, patients were most concerned about this cosmetic impairment. Another complaint concerned the scar and its position and structure. In 2 patients (3.7%) the scar was not completely covered by hair, whereas in 3 patients (5.7%) the scar color was clearly distinguishable from the color of the skin. One patient (1.8%) complained about the length of the scar. Details of cosmetic results are provided in Table 2.

**Discussion**

Due to partial removal of the orbital rim in the orbitozygomatic skull base approach, a higher approach-related morbidity as well as poorer cosmetic results could occur in comparison with the standard pterional approach. In general, results of our study demonstrate that the approach-related morbidity was comparable to the documented morbidity in pterional approaches or its modification without removing the orbital rim.

The occurrence of pneumocephalus after frontal craniotomy is not uncommon and usually resolves spontaneously within days. Yet if an exposed frontal sinus is not sufficiently exenterated and occluded, a persisting fistula enables air trapping and may even lead to epidural tension pneumocephalus.1 In 27 (38%) of our patients the opened frontal sinus required surgical reconstruction. Penetration of the frontal sinus was noted in 30% to 60% of patients when a supraorbital or orbitozygomatic approach was used, whereas the rate of sinus opening was 10% in patients undergoing pterional craniotomy.2–5

According to the literature the rate of CSF fistulas in this study is comparable to other large series.16,20 Careful examination of the medial bone margin and definite seal of open pneumatized cells along with watertight dural closure is crucial for avoiding CSF fistulas.

One patient suffered from intraorbital hematoma that necessitated surgical removal immediately. Typically intraorbital hematomas do not have such a severe effect and a wait-and-see strategy is justifiable. In our population some patients experienced transient venous congestion, usually without symptoms. If symptoms such as ptosis or proptosis occur and an orbital hematoma is present, a surgical removal might be necessary.

**TABLE 1: Minor and major complications in 71 patients within 30 days after the transorbital approach**

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. of Patients (%)</th>
</tr>
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<tbody>
<tr>
<td>none</td>
<td>51 (71.8)</td>
</tr>
<tr>
<td>reoperation (unrelated to surgical approach)</td>
<td>4 (5.6)</td>
</tr>
<tr>
<td>minor complication</td>
<td>12 (16.9)</td>
</tr>
<tr>
<td>hyposphagma due to orbital congestion (1 patient w/ ptosis)</td>
<td>2 (2.8)</td>
</tr>
<tr>
<td>facial nerve palsy of forehead branch</td>
<td>2 (2.8)</td>
</tr>
<tr>
<td>subgaleal collection of CSF</td>
<td>5 (7.0)</td>
</tr>
<tr>
<td>periorbital hematoma w/ periorbital swelling</td>
<td>2 (2.8)</td>
</tr>
<tr>
<td>subdural hematoma</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>major complication</td>
<td>4 (5.6)</td>
</tr>
<tr>
<td>CSF fistula</td>
<td>2 (2.8)</td>
</tr>
<tr>
<td>pneumocephalus</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>intraorbital hematoma</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>dead</td>
<td>4 (5.6)</td>
</tr>
</tbody>
</table>
Facial nerve palsy is one of the typical complications of frontotemporal surgical approaches and its occurrence is often not related to the craniotomy itself but rather to the applied skin incision and the dissection of the temporal muscle.\textsuperscript{12} In some cases a reduction in eyebrow mobility is not due to facial nerve injury, but to interruption of the insertion of the frontalis muscle on the eyebrow and forehead itself. Usually supraorbital decrease in eyebrow mobility is temporary and subsides within 3 to 6 months.\textsuperscript{8} However, retrograde subfascial dissection of the temporal muscle to expose the pterional keyhole helps to prevent injuries to the rami frontales and orbicularis, and when planning the skin incision one has to keep the course of the temporal facial nerve in mind.\textsuperscript{7,13,20}

Periorbital swelling, edema, or even hematoma is not uncommon in orbitocraniotomy, but it seldom poses a threat to the patient.\textsuperscript{8} Most of our patients showed a more or less distinct periorbital swelling that was usually not regarded as a complication. This was also observed in other patient series and similarly not regarded as a complication.\textsuperscript{10,20} A meticulous hemostasis before wound closure reduces periorbital swelling.

Persisting anosmia was present in 24.5\% of our patients. Surgeons using pterional approaches for treatment of ACoA aneurysms report an incidence of postoperative hyposmia or anosmia of 14\% to 39\%.\textsuperscript{4,14,19} Reisch and Pernczky,\textsuperscript{16} using a supraorbital subfrontal approach, report a lower incidence of only 6\% of unilateral anosmia and 2\% bilateral or total anosmia. However, the impact of the SAH itself on olfaction, particularly from ACoA aneurysms, remains unclear because there are a number of patients losing olfaction without cranial surgery.\textsuperscript{14}

Overall cosmetic outcome was good. More than 90\% of the examined patients had no or only minor complaints about the cosmetic results of the surgical approach. Complaints in this group were mostly concerned with the scar and not with the craniotomy itself. The cause of dissatisfaction in patients with moderate or good cosmetic outcome was primarily atrophy of the temporal muscle. Atrophy of the temporal muscle is a common problem of frontotemporal approaches, especially when an extensive detachment of the muscle is necessary.\textsuperscript{8} We recommend only a minimal detachment of the temporal muscle just to expose the pterional keyhole. A subfascial detachment of the muscle avoids injury to the facial nerve and ensures proper refixation. We reattached the muscle with sutures to the bone through 2 small holes that were drilled along the orbitozygomatic superior orbital line as described by Bowles.\textsuperscript{5}

Visible bur holes caused by skin indentation over the bone flap leading to asymmetry of the orbit rim and the forehead were present in 2 patients. In both patients the bur holes were not filled up with methylmethacrylate bone cement. To avoid visible bur holes in the orbital rim we
recommend use of methylmethacrylate bone cement to fill up the holes and the gap between bone flap and frontal bone. The bone flap itself underwent refixation using microplates and screws. One plate is placed laterally so that it is completely covered by the reattached muscle.

Conclusions

The transorbital keyhole approach is a convenient and simple approach, especially for the ACoA complex. The present systematic analysis demonstrates a low morbidity and excellent cosmetic outcome in the majority of patients. This approach provides a safe extraaxial passage, reducing the necessity of brain retraction, and therefore adds a feasible tool to the armamentarium of minimally invasive approaches to the anterior skull base including the ACoA complex.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Beseoglu, Lodes, Steiger, Hänggi. Acquisition of data: Beseoglu, Lodes. Analysis and interpretation of data: Beseoglu, Lodes. Drafting the article: Lodes, Hänggi. Critically revising the article: Stummer, Steiger, Hänggi. Reviewed final version of the manuscript and approved it for submission: all authors. Statistical analysis: Beseoglu. Study supervision: Steiger, Hänggi.

References


 TABLE 2: Self-rated patient cosmetic complaints after the transorbital keyhole approach*  

<table>
<thead>
<tr>
<th>Rating</th>
<th>No. of Patients (%)</th>
<th>Complaints (No. of Patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>very good</td>
<td>35 (64.8)</td>
<td>no complaints (35)</td>
</tr>
<tr>
<td>good</td>
<td>14 (25.9)</td>
<td>scar too long (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>scar not in hairline (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>scar color (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>minor muscle atrophy (7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>no comment (2)</td>
</tr>
<tr>
<td>moderate</td>
<td>4 (7.4)</td>
<td>visible muscle atrophy (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>skin indention over bur holes (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>scar not in hairline (1)</td>
</tr>
<tr>
<td>poor</td>
<td>1 (1.8)</td>
<td>major muscle atrophy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bur holes clearly visible (1)</td>
</tr>
</tbody>
</table>

* Fifty-four patients provided evaluations of cosmetic results.